National Semiconductor

October 2007

LME49721
High Performance, High Fidelity Rail-to-Rail Input/Output Audio Operational Amplifier

General Description

The LME49721 is a low distortion, low noise Rail-to-Rail Input/Output operational amplifier optimized and fully specified for high performance, high fidelity applications. Combining advanced leading-edge process technology with state-of-the-art circuit design, the LME49721 Rail-to-Rail Input/Output operational amplifier delivers superior signal amplification for outstanding performance. The LME49721 combines a very high slew rate with low THD+N to easily satisfy demanding applications. To ensure that the most challenging loads are driven without compromise, the LME49721 has a high slew rate of ±8.5V/μs and an output current capability of ±9.7mA. Further, dynamic range is maximized by an output stage that drives 10kΩ loads to within 10mV of either power supply voltage.

The LME49721 has a wide supply range of 2.2V to 5.5V. Over this supply range the LME49721's input circuitry maintains excellent common-mode and power supply rejection, as well as maintaining its low input bias current. The LME49721 is unity gain stable.

Key Specifications

■ Power Supply Voltage Range	2.2V to 5.5V
■ Quiescent Current	2.15mA (typ)
■ THD+N ($A_V = 2$, $V_{OUT} = 4V_{p\text{-}p}$, $f_{IN} = 1kHz$)	
R_L = 2kΩ	0.00008% (typ)
R_L = 600Ω	0.0001% (typ)
■ Input Noise Density	4nV/√Hz (typ), @ 1kHz
■ Slew Rate	±8.5V/μs (typ)
■ Gain Bandwidth Product	20MHz (typ)
■ Open Loop Gain (R_L = 600Ω)	118dB (typ)
■ Input Bias Current	40fA (typ)
■ Input Offset Voltage	0.3mV (typ)
■ PSRR	103dB (typ)

Features

- Rail-to-rail Input and Output
- Easily drives 10kΩ loads to within 10mV of each power supply voltage
- Optimized for superior audio signal fidelity
- Output short circuit protection

Applications

- Ultra high quality portable audio amplification
- High fidelity preamplifiers
- High fidelity multimedia
- State of the art phono pre amps
- High performance professional audio
- High fidelity equalization and crossover networks
- High performance line drivers
- High performance line receivers
- High fidelity active filters
- DAC I–V converter
- ADC front-end signal conditioning

Typical Connection, Pinout, and Package Marking

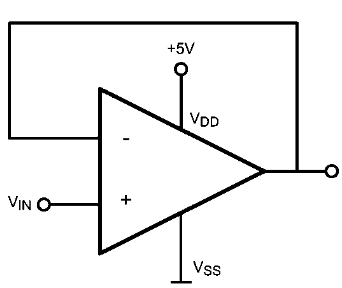
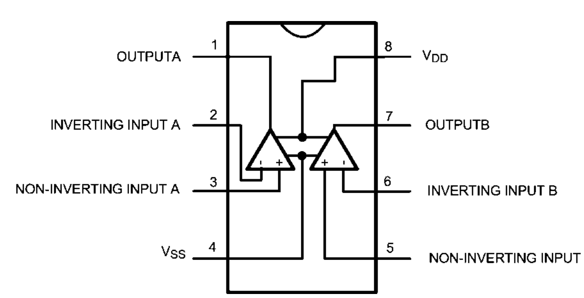
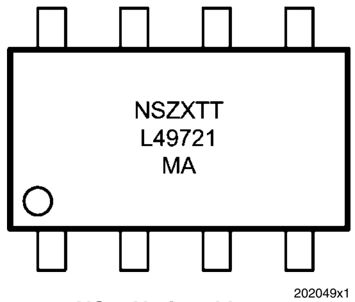


FIGURE 1. Buffer Amplifier



Order Number LME49721MA
Se NS Package Number M08A

Package Marking



NS = National Logo
Z = Assembly plant code
X = 1 Digit date code
TT = Lot traceability
L49721 = LME49721
MA = Narrow SOIC package code

Absolute Maximum Ratings (Notes 1, 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Power Supply Voltage ($V_S = V^+ - V^-$)	6V
Storage Temperature	−65°C to 150°C
Input Voltage	(V-) - 0.7V to (V+) + 0.7V
Output Short Circuit (Note 3)	Continuous
Power Dissipation	Internally Limited
ESD Rating (Note 4)	2000V
ESD Rating (Note 5)	200V
Junction Temperature	150°C
Thermal Resistance	
θ_{JA} (SO)	165°C/W
Temperature Range	
$T_{MIN} \le T_A \le T_{MAX}$	$-40°C \le T_A \le 85°C$
Supply Voltage Range	$2.2V \le V_S \le 5.5V$

Electrical Characteristics for the LME49721

The following specifications apply for the circuit shown in Figure 1. $V_S = 5V$, $R_L = 10k\Omega$, $R_{SOURCE} = 10\Omega$, $f_{IN} = 1kHz$, and $T_A = 25°C$, unless otherwise specified.

Symbol	Parameter	Conditions	LME49721 Typical (Note 6)	LME49721 Limit (Note 7)	Units (Limits)
THD+N	Total Harmonic Distortion + Noise	$A_V = +1$, $V_{OUT} = 2V_{p-p}$, $R_L = 2k\Omega$	0.0002		
		$R_L = 600\Omega$	0.0002	0.001	% (max)
IMD	Intermodulation Distortion	$A_V = +1$, $V_{OUT} = 2V_{p-p}$, Two-tone, 60Hz & 7kHz 4:1	0.0004		%
GBWP	Gain Bandwidth Product		20	15	MHz (min)
SR	Slew Rate	$A_V = +1$	8.5		V/μs (min)
FPBW	Full Power Bandwidth	$V_{OUT} = 1V_{P-P}$, –3dB referenced to output magnitude at f = 1kHz	2.2		MHz
t_s	Settling time	$A_V = 1$, 4V step 0.1% error range	800		ns
e_n	Equivalent Input Noise Voltage	f_{BW} = 20Hz to 20kHz, A-weighted	.707	1.13	μV_{P-P} (max)
	Equivalent Input Noise Density	f = 1kHz A-weighted	4	6	$nV/\sqrt{Hz}$ (max)
i_n	Current Noise Density	f = 10kHz	4.0		$fA/\sqrt{Hz}$
V_{OS}	Offset Voltage		0.3	1.5	mV (max)
$\Delta V_{OS}/\Delta Temp$	Average Input Offset Voltage Drift vs Temperature	$40°C \le T_A \le 85°C$	1.1		μV/°C
PSRR	Average Input Offset Voltage Shift vs Power Supply Voltage		103	85	dB (min)
ISO_{CH-CH}	Channel-to-Channel Isolation	f_{IN} = 1kHz	117		dB
I_B	Input Bias Current	$V_{CM} = V_S/2$	40		fA
$\Delta I_{OS}/\Delta Temp$	Input Bias Current Drift vs Temperature	$-40°C \le T_A \le 85°C$	48		fA/°C
I_{OS}	Input Offset Current	$V_{CM} = V_S/2$	60		fA
V_{IN-CM}	Common-Mode Input Voltage Range			(V+) – 0.1 (V-) + 0.1	V (min)
CMRR	Common-Mode Rejection	$V_{SS} - 100mV < V_{CM} < V_{DD} + 100mV$	93	70	dB (min)
	1/f Corner Frequency		2000		Hz
A_{VOL}	Open Loop Voltage Gain	$V_{SS} - 200mV < V_{OUT} < V_{DD} + 200mV$			
		$R_L = 600\Omega$	118	100	dB (min)
		$R_L = 2k\Omega$	122		dB (min)
		$R_L = 10k\Omega$	130	115	dB (min)

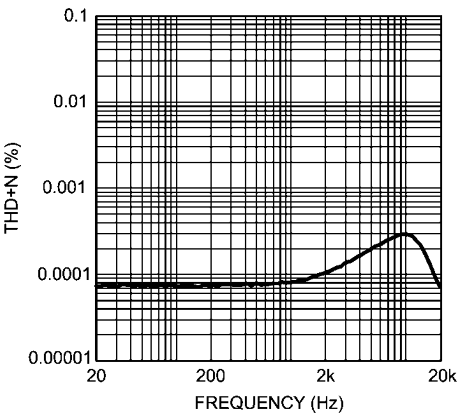
Symbol	Parameter	Conditions	LME49721		Units (Limits)
			Typical (Note 6)	Limit (Note 7)	
V_{OUTMIN}	Output Voltage Swing	$R_L = 600\Omega$	V_{DD} – 30mV	V_{DD} – 80mV	V (min)
			V_{SS} + 30mV	V_{SS} + 80mV	V (min)
		$R_L = 10k\Omega$, V_S = 5.0V	V_{DD} – 10mV	V_{DD} – 20mV	V (min)
			V_{SS} + 10mV	V_{SS} + 20mV	V (min)
I_{OUT}	Output Current	$R_L = 250\Omega$, V_S = 5.0V	9.7	9.3	mA (min)
I_{OUT-SC}	Short Circuit Current		100		mA
R_{OUT}	Output Impedance	f_{IN} = 10kHz Closed-Loop Open-Loop	 0.01 46		Ω
I_S	Quiescent Current per Amplifier	I_{OUT} = 0mA	2.15	3.25	mA (max)

Note 1: "*Absolute Maximum Ratings*" indicate limits beyond which damage to the device may occur, including inoperability and degradation of device reliability and/or performance. Functional operation of the device and/or non-degradation at the *Absolute Maximum Ratings* or other conditions beyond those indicated in the Recommended Operating Conditions is not implied. The *Recommended Operating Conditions* indicate conditions at which the device is functional and the

Typical Performance Characteristics

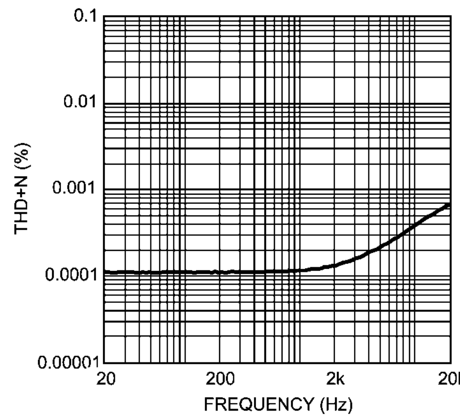
Graphs were taken in dual supply configuration.

THD+N vs Frequency
V_S = ±2.5V, V_{OUT} = $4V_{P-P}$
R_L = 2kΩ, A_V = 2, BW = 22kHz



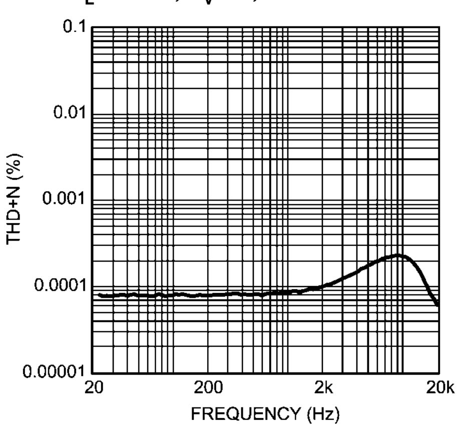
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THD+N vs Frequency
V_S = ±2.5V, V_{OUT} = $4V_{P-P}$
R_L = 2kΩ, A_V = 2



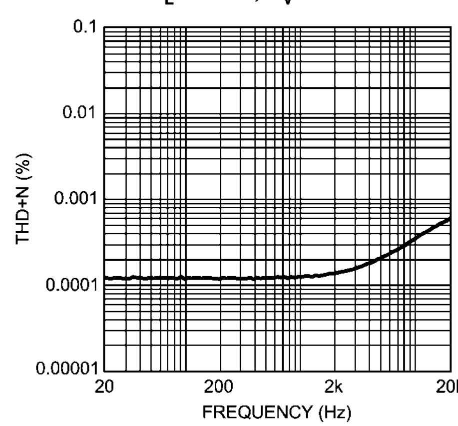
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THD+N vs Frequency
V_S = ±2.5V, V_{OUT} = $4V_{P-P}$
R_L = 10kΩ, A_V = 2, BW = 22kHz



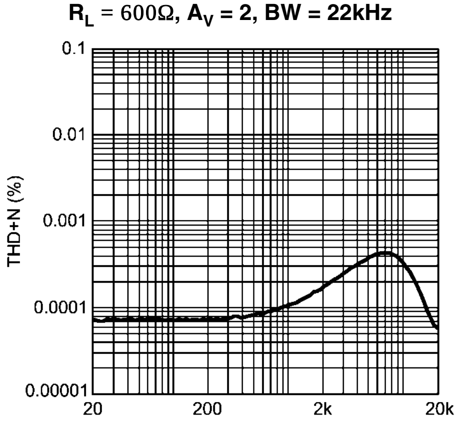
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THD+N vs Frequency
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R_L = 10kΩ, A_V = 2



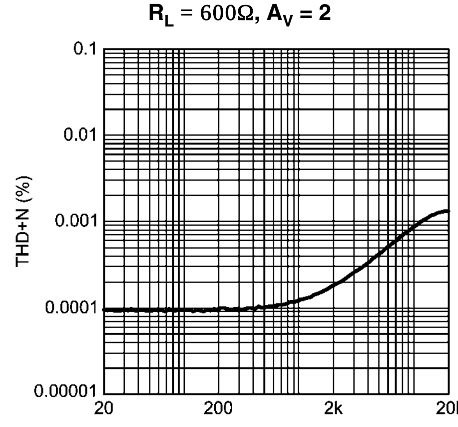
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THD+N vs Frequency
V_S = ±2.5V, V_{OUT} = $4V_{P-P}$
R_L = 600Ω, A_V = 2, BW = 22kHz



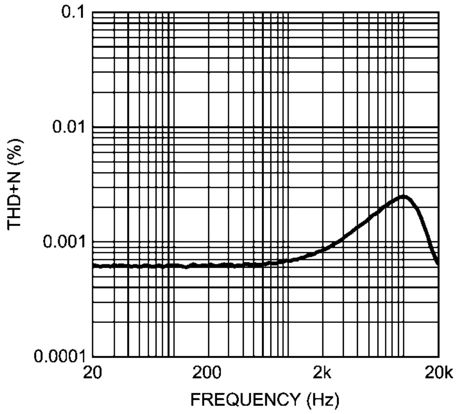
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THD+N vs Frequency
V_S = ±2.5V, V_{OUT} = $4V_{P-P}$
R_L = 600Ω, A_V = 2



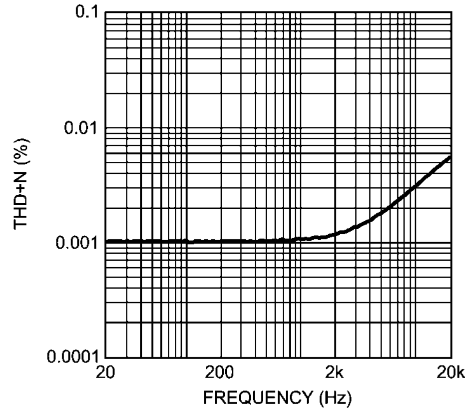
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THD+N vs Frequency
V_S = ±2.75V, V_{OUT} = 4V_{P-P}
R_L = 2kΩ, A_V = 2, BW = 22kHz



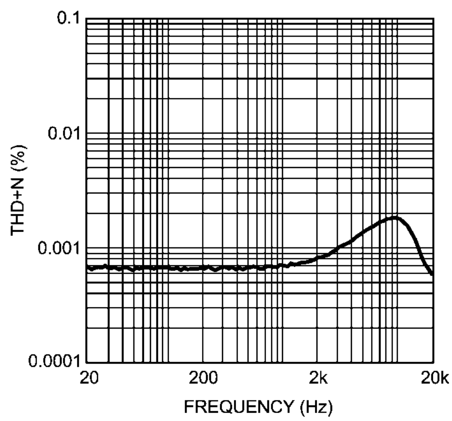
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THD+N vs Frequency
V_S = ±2.75V, V_{OUT} = 4V_{P-P}
R_L = 2kΩ, A_V = 2



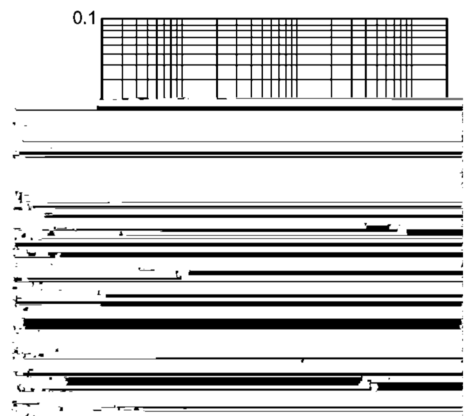
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THD+N vs Frequency
V_S = ±2.75V, V_{OUT} = 4V_{P-P}
R_L = 10kΩ, A_V = 2, BW = 22kHz



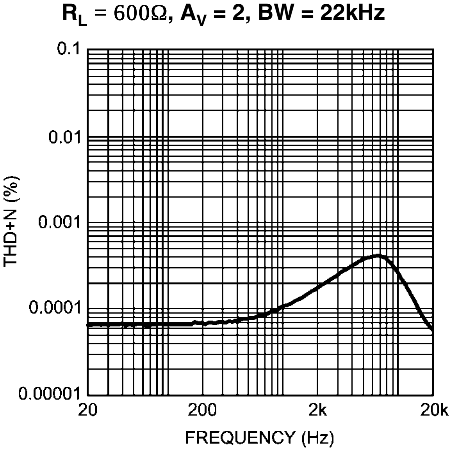
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THD+N vs Frequency
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R_L = 10kΩ, A_V = 2



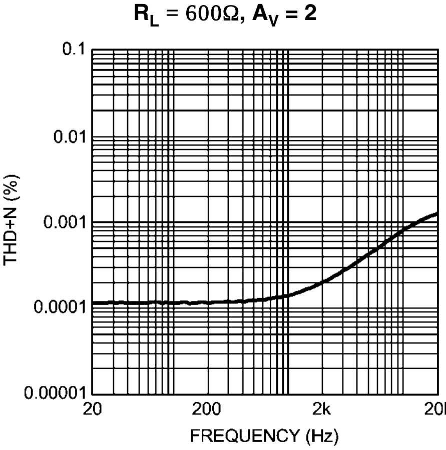
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THD+N vs Frequency
V_S = ±2.75V, V_{OUT} = 4V_{P-P}
R_L = 600Ω, A_V = 2, BW = 22kHz



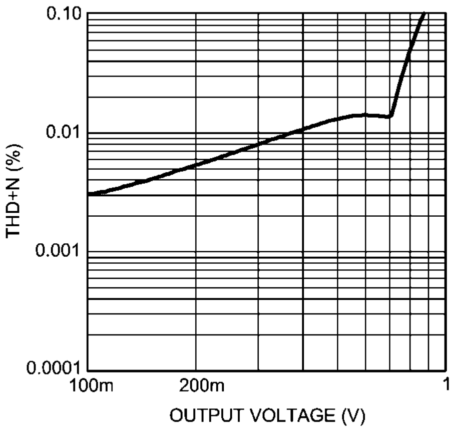
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THD+N vs Frequency
V_S = ±2.75V, V_{OUT} = 4V_{P-P}
R_L = 600Ω, A_V = 2



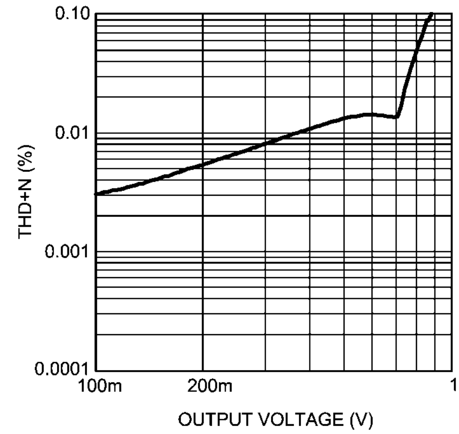
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THD+N vs Output Voltage
V_S = ±1.1V
R_L = 2kΩ, A_V = 2



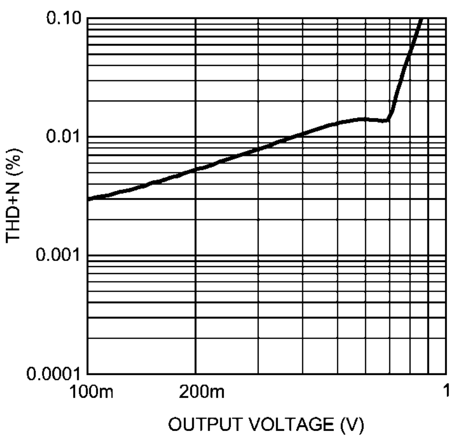
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THD+N vs Output Voltage
V_S = ±1.1V
R_L = 10kΩ, A_V = 2



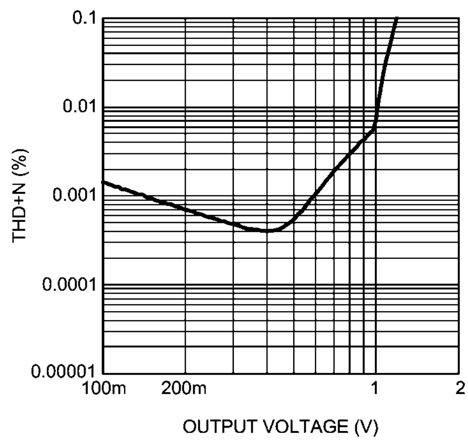
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THD+N vs Output Voltage
V_S = ±1.1V
R_L = 600Ω, A_V = 2



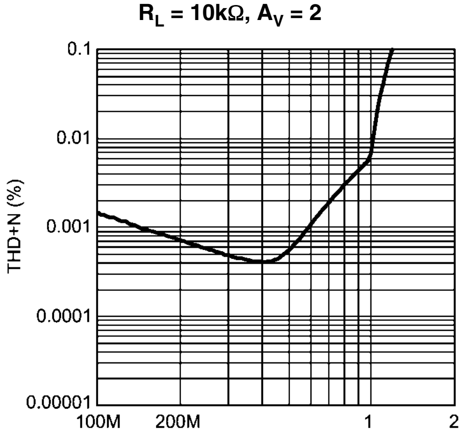
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THD+N vs Output Voltage
V_S = ±1.5V
R_L = 2kΩ, A_V = 2



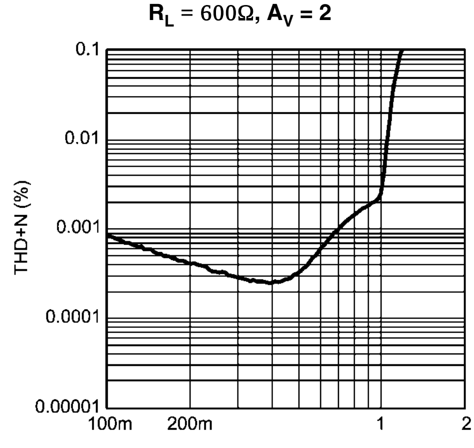
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THD+N vs Output Voltage
V_S = ±1.5V
R_L = 10kΩ, A_V = 2



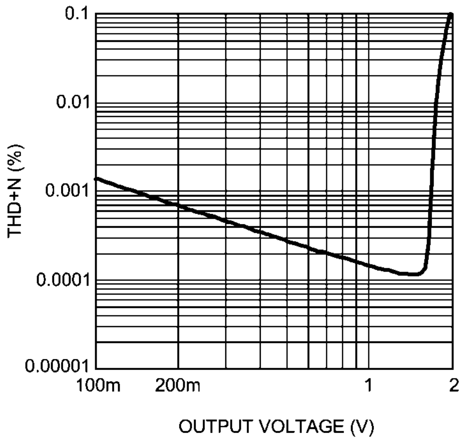
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THD+N vs Output Voltage
V_S = ±1.5V
R_L = 600Ω, A_V = 2



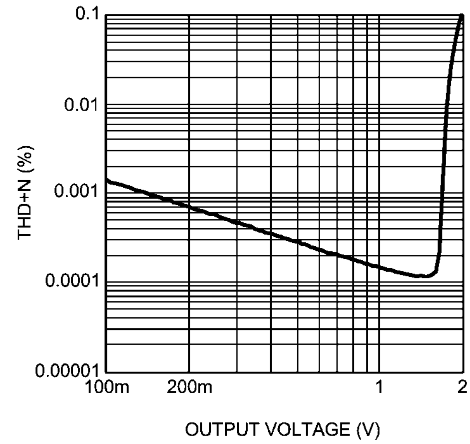
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THD+N vs Output Voltage
V_S = ±2.5V
R_L = 2kΩ, A_V = 2



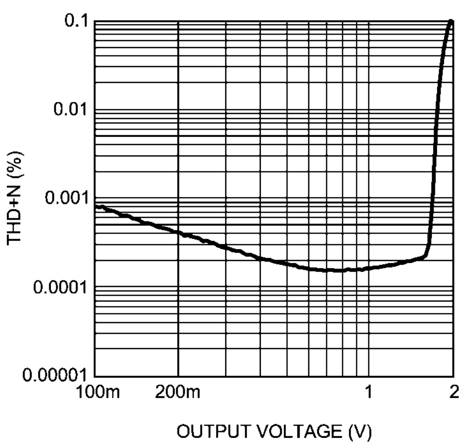
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THD+N vs Output Voltage
V_S = ±2.5V
R_L = 10kΩ, A_V = 2



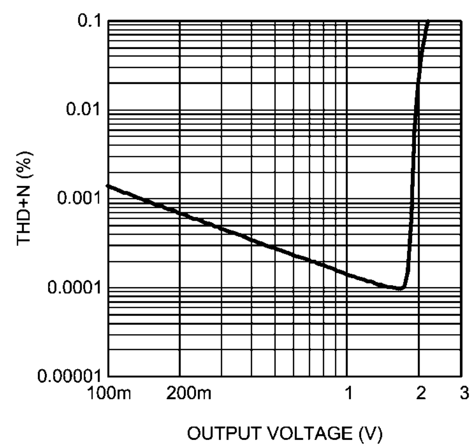
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THD+N vs Output Voltage
V_S = ±2.5V
R_L = 600Ω, A_V = 2



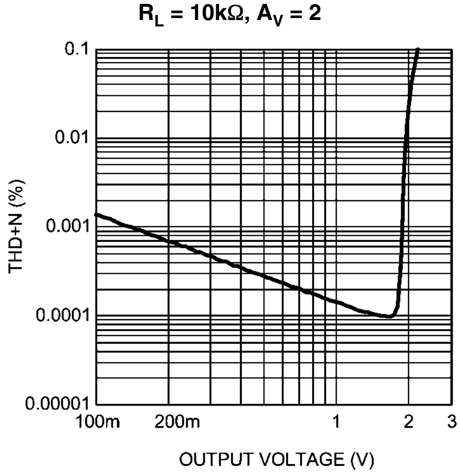
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THD+N vs Output Voltage
V_S = ±2.75V
R_L = 2kΩ, A_V = 2



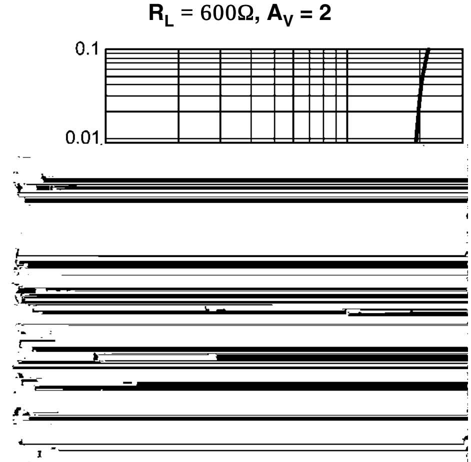
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THD+N vs Output Voltage
V_S = ±2.75V
R_L = 10kΩ, A_V = 2



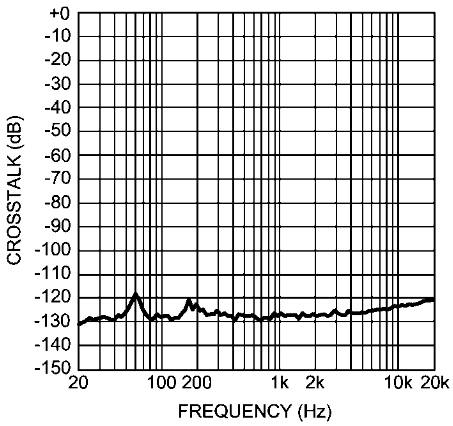
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THD+N vs Output Voltage
V_S = ±2.75V
R_L = 600Ω, A_V = 2



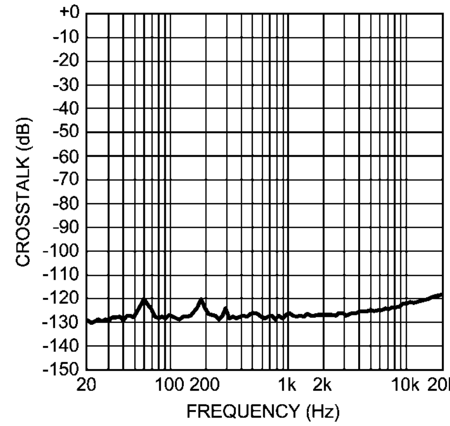
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Crosstalk vs Frequency
V_S = ±1.1V
V_{OUT} = 2V_{p-p}
R_L = 2kΩ



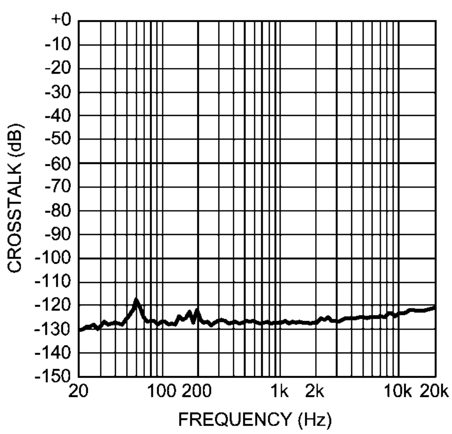
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Crosstalk vs Frequency
V_S = ±1.1V
V_{OUT} = 2V_{p-p}
R_L = 10kΩ



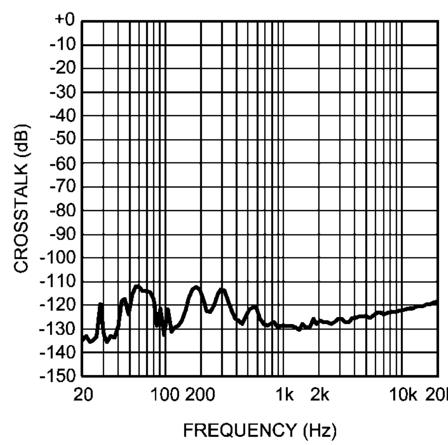
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Crosstalk vs Frequency
V_S = ±1.1V
V_{OUT} = 2V_{p-p}
R_L = 600Ω



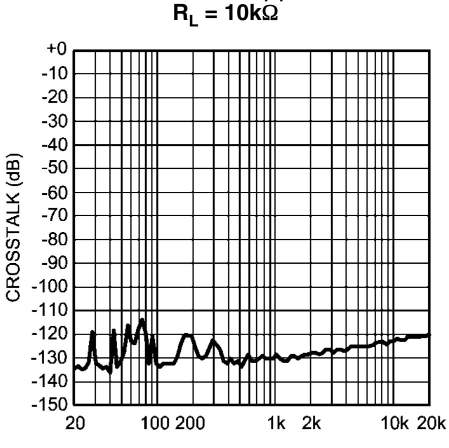
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Crosstalk vs Frequency
V_S = ±1.5V,
V_{OUT} = 2V_{p-p}
R_L = 2kΩ



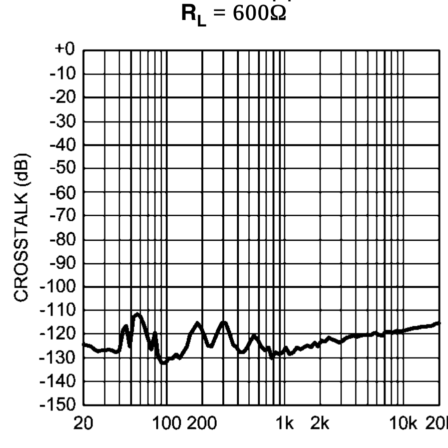
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Crosstalk vs Frequency
V_S = ±1.5V
V_{OUT} = 2V_{p-p}
R_L = 10kΩ



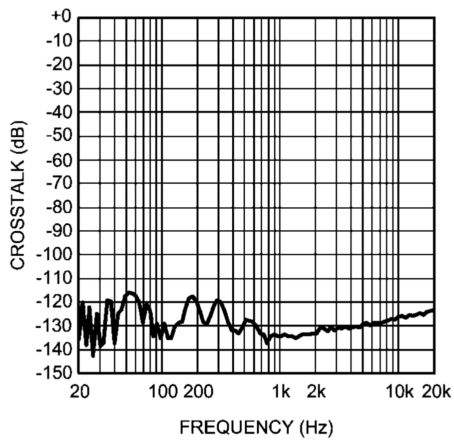
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Crosstalk vs Frequency
V_S = ±1.5V
V_{OUT} = 2V_{p-p}
R_L = 600Ω



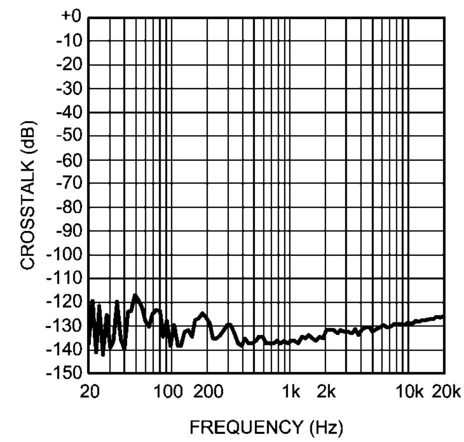
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Crosstalk vs Frequency
$V_S = \pm 2.5V$
$V_{OUT} = 4V_{p-p}$
$R_L = 2k\Omega$



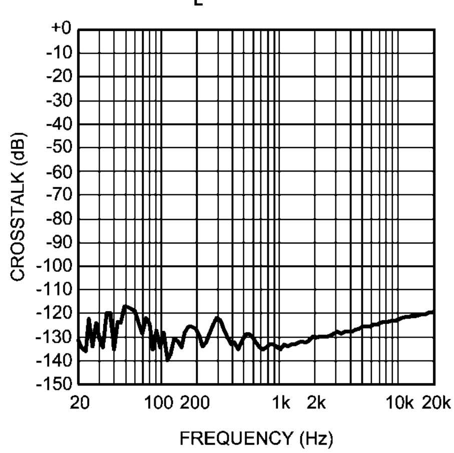
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Crosstalk vs Frequency
$V_S = \pm 2.5V$
$V_{OUT} = 4V_{p-p}$
$R_L = 10k\Omega$



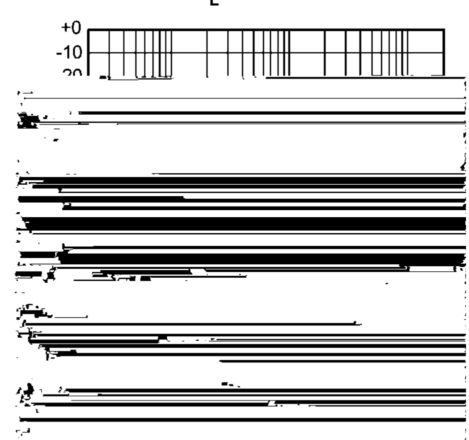
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Crosstalk vs Frequency
$V_S = \pm 2.5V$
$V_{OUT} = 4V_{p-p}$
$R_L = 600\Omega$



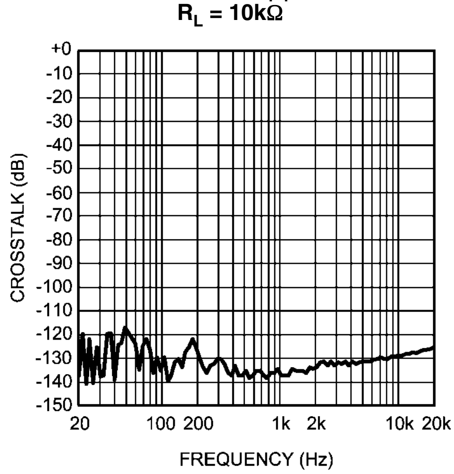
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Crosstalk vs Frequency
$V_S = \pm 2.75V$
$V_{OUT} = 4V_{p-p}$
$R_L = 2k\Omega$



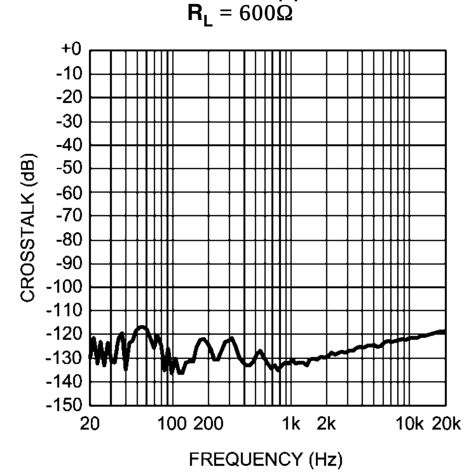
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Crosstalk vs Frequency
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$V_{OUT} = 4V_{p-p}$
$R_L = 10k\Omega$



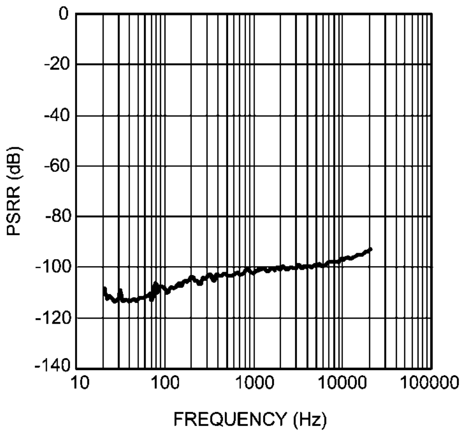
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Crosstalk vs Frequency
$V_S = \pm 2.75V$
$V_{OUT} = 4V_{p-p}$
$R_L = 600\Omega$



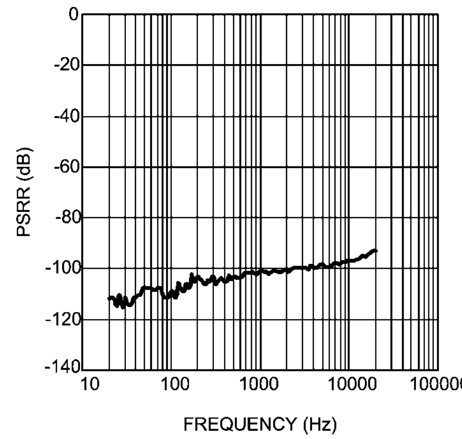
202049k9

PSRR vs Frequency
$V_S = \pm1.1V$
$V_{RIPPLE} = 200mV_{P-P}$
$R_L = 2k\Omega$



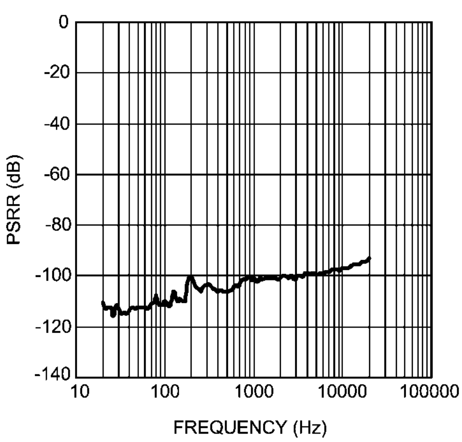
202049v9

PSRR vs Frequency
$V_S = \pm1.1V$
$V_{RIPPLE} = 200mV_{P-P}$
$R_L = 10k\Omega$



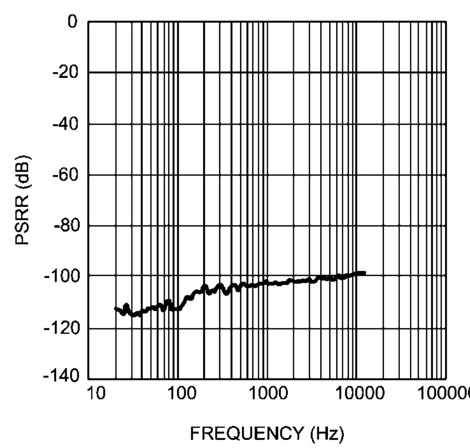
202049w0

PSRR vs Frequency
$V_S = \pm1.1V$
$V_{RIPPLE} = 200mV_{P-P}$
$R_L = 600\Omega$



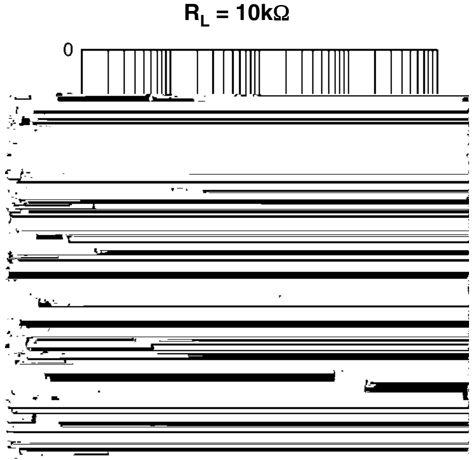
202049w1

PSRR vs Frequency
$V_S = \pm1.5V$
$V_{RIPPLE} = 200mV_{P-P}$
$R_L = 2k\Omega$



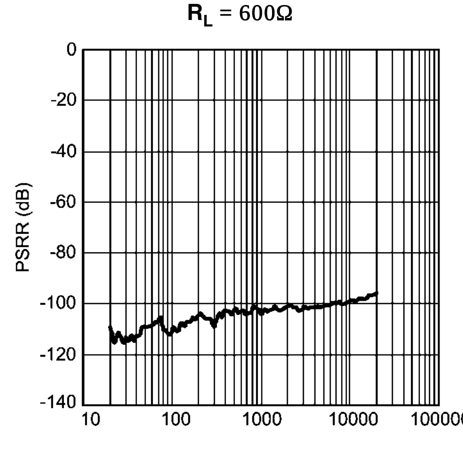
202049w2

PSRR vs Frequency
$V_S = \pm1.5V$
$V_{RIPPLE} = 200mV_{P-P}$
$R_L = 10k\Omega$



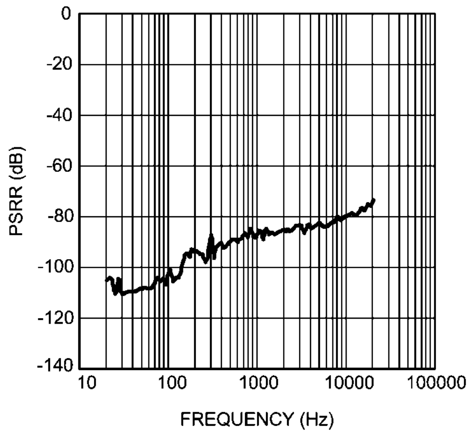
202049w3

PSRR vs Frequency
$V_S = \pm1.5V$
$V_{RIPPLE} = 200mV_{P-P}$
$R_L = 600\Omega$



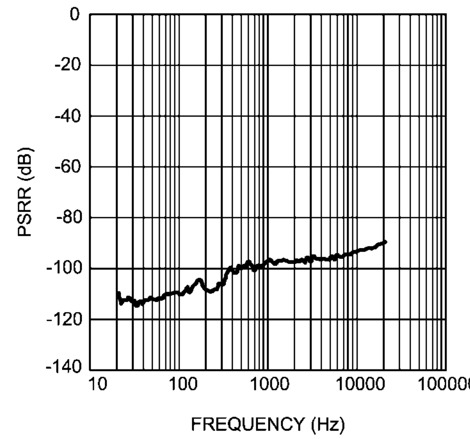
202049x4

PSRR vs Frequency
V_S = ±2.5V
V_{RIPPLE} = 200mV_{P-P}
R_L = 2kΩ



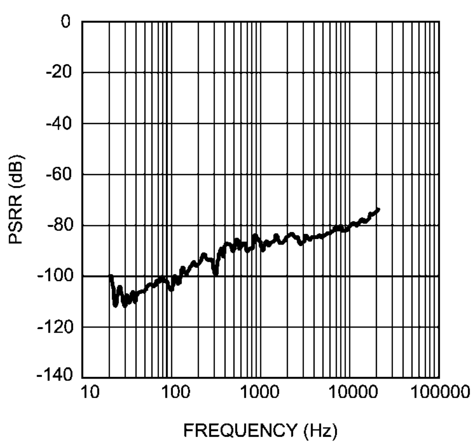
202049w5

PSRR vs Frequency
V_S = ±2.5V
V_{RIPPLE} = 200mV_{P-P}
R_L = 10kΩ



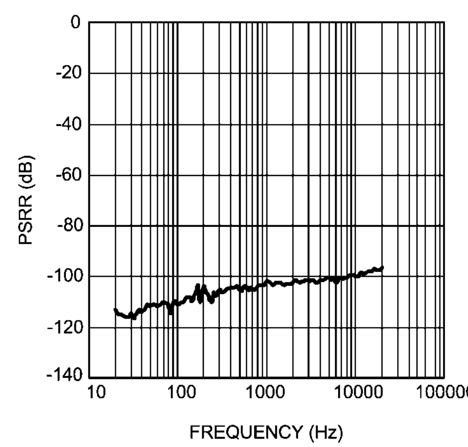
202049w6

PSRR vs Frequency
V_S = ±2.5V
V_{RIPPLE} = 200mV_{P-P}
R_L = 600Ω



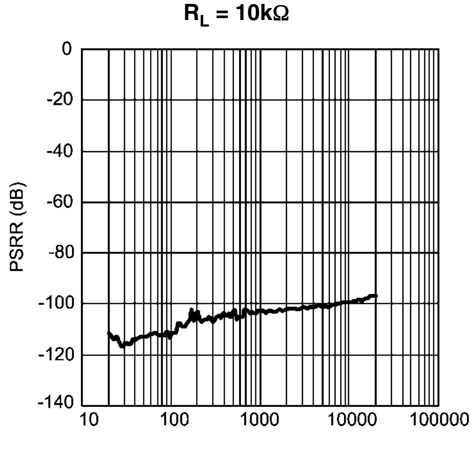
202049w7

PSRR vs Frequency
V_S = ±2.75V
V_{RIPPLE} = 200mV_{P-P}
R_L = 2kΩ



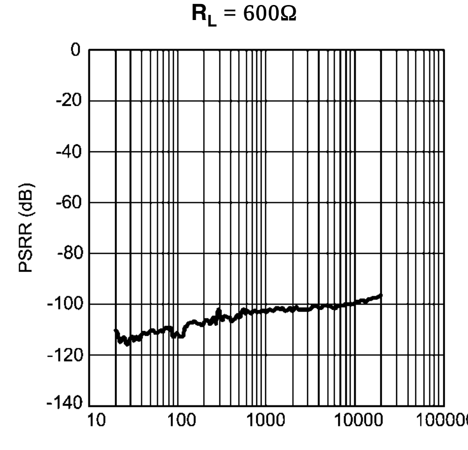
202049w8

PSRR vs Frequency
V_S = ±2.75V
V_{RIPPLE} = 200mV_{P-P}
R_L = 10kΩ



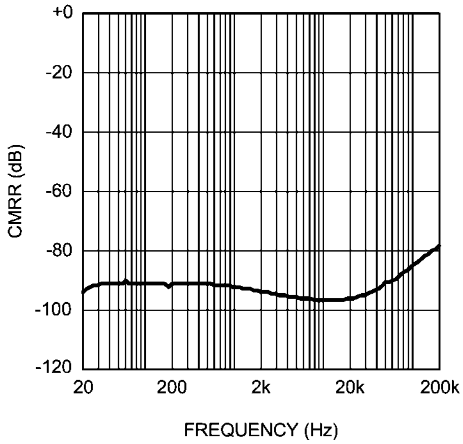
202049w9

PSRR vs Frequency
V_S = ±2.75V
V_{RIPPLE} = 200mV_{P-P}
R_L = 600Ω



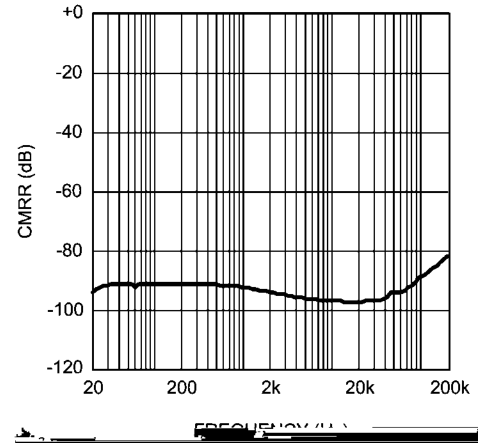
202049x0

CMRR vs Frequency
V_S = ±1.5V
R_L = 2kΩ



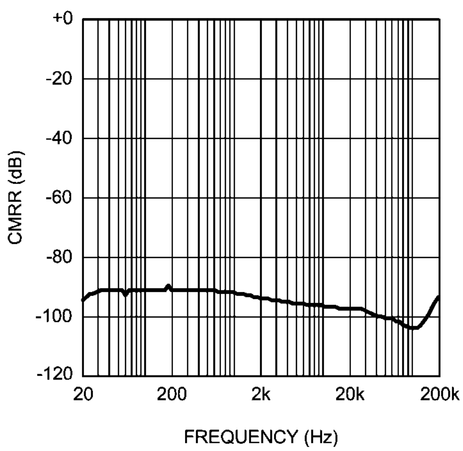
202049I3

CMRR vs Frequency
V_S = ±1.5V
R_L = 10kΩ



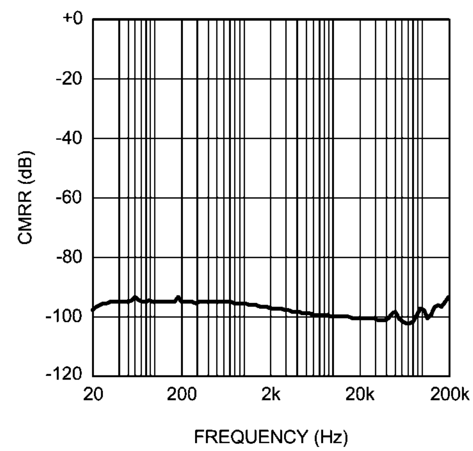
202049I4

CMRR vs Frequency
V_S = ±1.5V
R_L = 600Ω



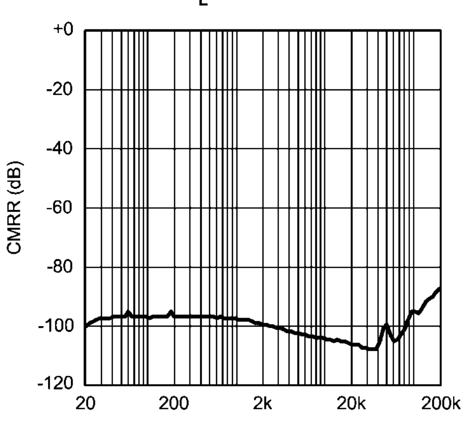
202049I5

CMRR vs Frequency
V_S = ±2.5V
R_L = 2kΩ



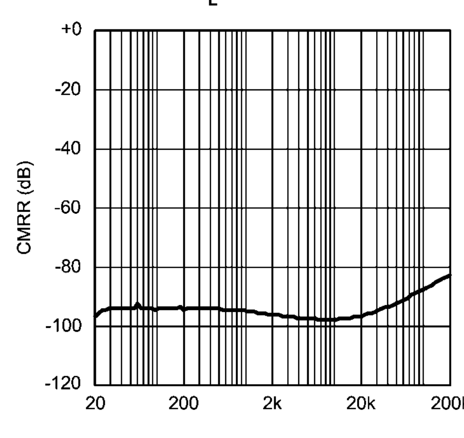
202049I6

CMRR vs Frequency
V_S = ±2.5V
R_L = 10kΩ



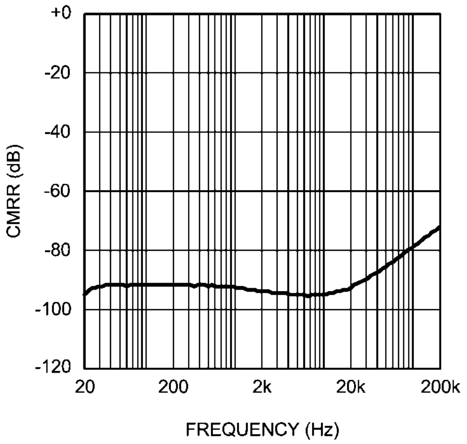
202049I7

CMRR vs Frequency
V_S = ±2.5V
R_L = 600Ω



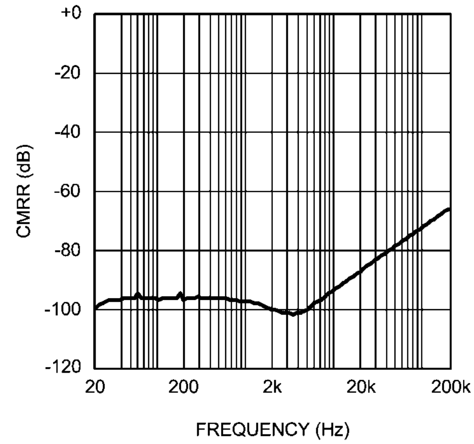
202049I8

CMRR vs Frequency
V_S = ±2.75V
R_L = 2kΩ



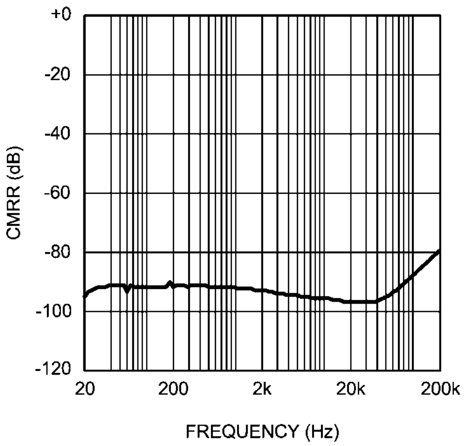
202049l9

CMRR vs Frequency
V_S = ±2.75V
R_L = 10kΩ



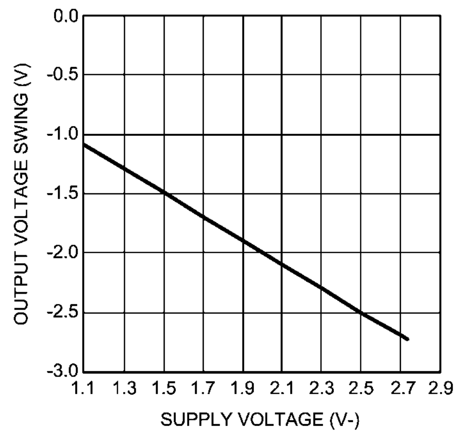
202049m0

CMRR vs Frequency
V_S = ±2.75V
R_L = 600Ω



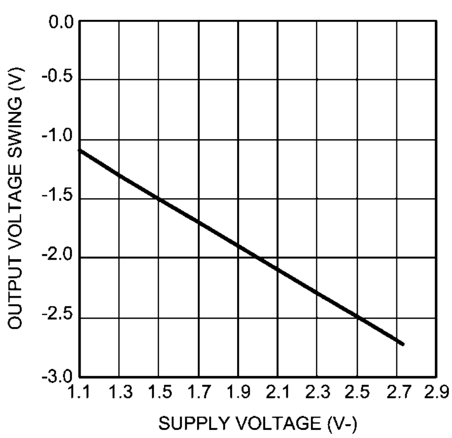
202049m1

Output Voltage Swing Neg vs Power Supply
R_L = 2kΩ



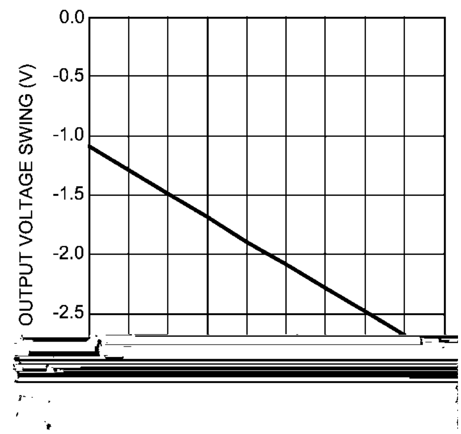
202049s9

Output Voltage Swing Neg vs Power Supply
R_L = 10kΩ



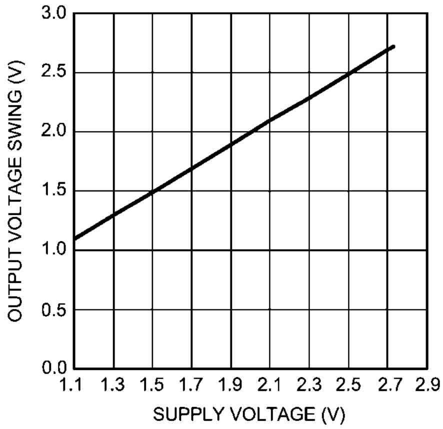
202049t0

Output Voltage Swing Neg vs Power Supply
R_L = 600Ω



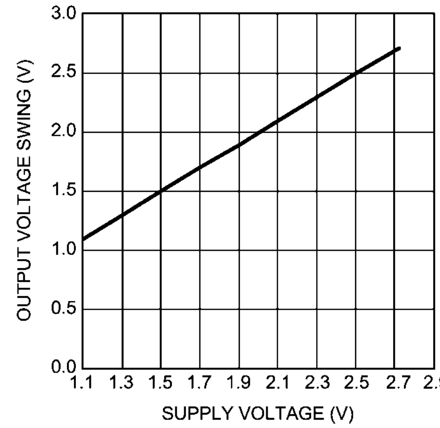
202049t1

Output Voltage Swing Pos vs Power Supply
R_L = 2kΩ



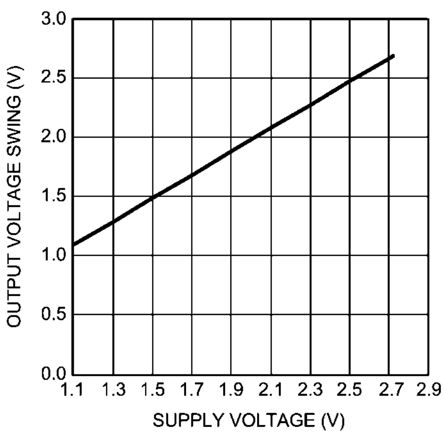
202049t2

Output Voltage Swing Pos vs Power Supply
R_L = 10kΩ



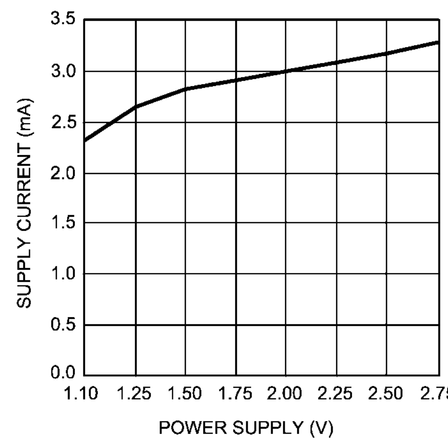
202049t3

Output Voltage Swing Pos vs Power Supply
R_L = 600Ω



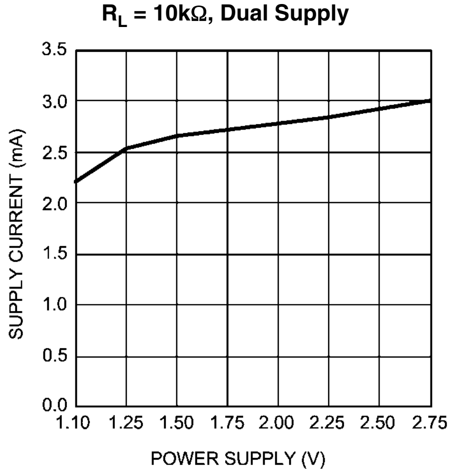
202049t4

Supply Current per amplifier vs Power Supply
R_L = 2kΩ, Dual Supply



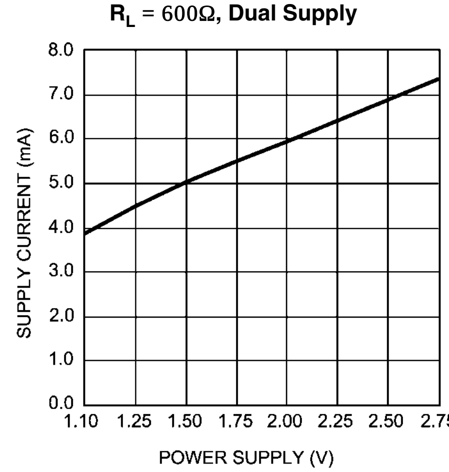
20204953

Supply Current per amplifier vs Power Supply
R_L = 10kΩ, Dual Supply



20204954

Supply Current per amplifier vs Power Supply
R_L = 600Ω, Dual Supply



20204956

Application Information

DISTORTION MEASUREMENTS

The vanishingly low residual distortion produced by LME49721 is below the capabilities of all commercially available equipment. This makes distortion measurements just slightly more difficult than simply connecting a distortion meter to the amplifier's inputs and outputs. The solution. however, is quite simple: an additional resistor. Adding this resistor extends the resolution of the distortion measurement equipment.

The LME49721's low residual is an input referred internal error. As shown in Figure 1, adding the 10Ω resistor connected between athe amplifier's inverting and non-inverting inputs changes the amplifier's noise gain. The result is that the error signal (distortion) is amplified by a factor of 101. Although the amplifier's closed-loop gain is unaltered, the feedback available to correct distortion errors is reduced by 101. To ensure minimum effects on distortion measurements, keep the value of R1 low as shown in Figure 1.

This technique is verified by duplicating the measurements with high closed loop gain and/or making the measurements at high frequencies. Doing so, produces distortion components that are within equipments capabilities. This datasheet's THD+N and IMD values were generated using the above described circuit connected to an Audio Precision System Two Cascade.

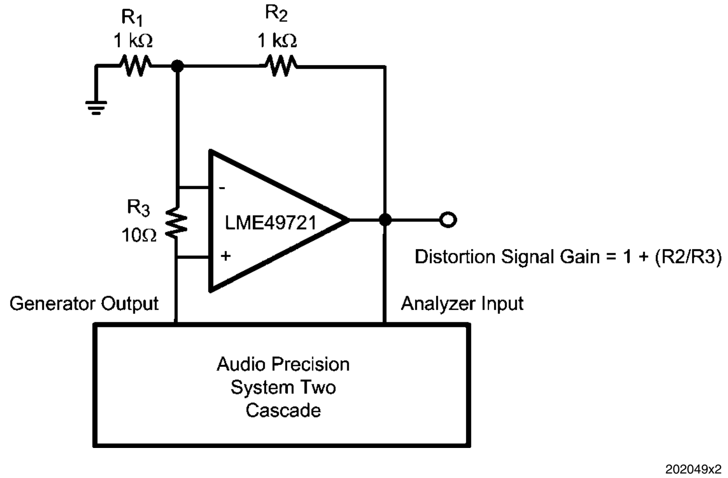


FIGURE 1. THD+N and IMD Distortion Test Circuit with A_V = 2

OPERATING RATINGS AND BASIC DESIGN GUIDELINES

The LME49721 has a supply voltage range from +2.2V to +5.5V single supply or ±1.1 to ±2.75V dual supply.

Bypassed capacitors for the supplies should be placed as close to the amplifier as possible. This will help minimize any inductance between the power supply and the supply pins. In addition to a 10µF capacitor, a 0.1µF capacitor is also recommended in CMOS amplifiers.

The amplifier's inputs lead lengths should also be as short as possible. If the op amp does not have a bypass capacitor, it may oscillate.

BASIC AMPLIFIER CONFIGURATIONS

The LME49721 may be operated with either a single supply or dual supplies. Figure 2 shows the typical connection for a single supply inverting amplifier. The output voltage for a single supply amplifier will be centered around the common-mode voltage Vcm. Note, the voltage applied to the Vcm insures the output stays above ground. Typically, the Vcm should be equal to $V_{DD}/2$. This is done by putting a resistor divider ckt at this node, see Figure 2.

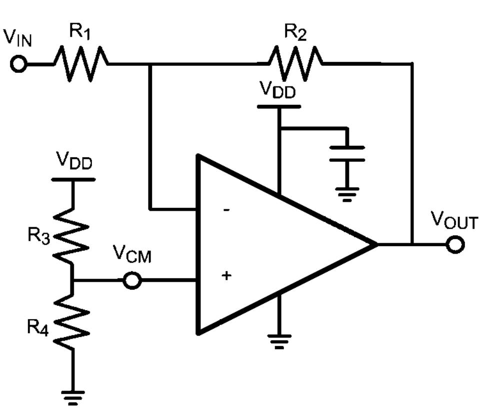


FIGURE 2. Single Supply Inverting Op Amp

Figure 3 shows the typical connection for a dual supply inverting amplifier. The output voltage is centered on zero.

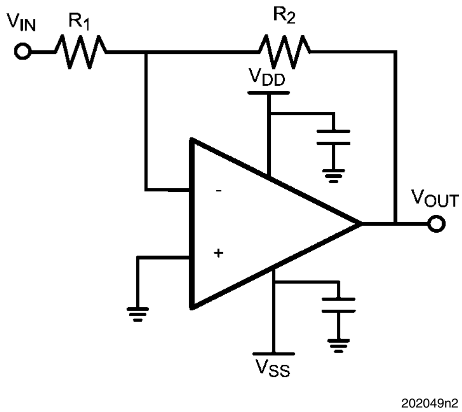


FIGURE 3. Dual Supply Inverting Op Amp

Figure 4 shows the typical connection for the Buffer Amplifier or also called a Voltage Follower. A Buffer Amplifier can be used to solve impedance matching problems, to reduce power consumption in the source, or to drive heavy loads. The input impedance of the op amp is very high. Therefore, the input of the op amp does not load down the source. The output impedance on the other hand is very low. It allows the load to either supply or absorb energy to a circuit while a secondary voltage source dissipates energy from a circuit. The Buffer is a unity stable amplifier, 1V/V. Although the feedback loop is tied from the output of the amplifier to the inverting input, the gain is still positive. Note, if a positive feedback is used, the amplifier will most likely drive to either rail at the output.

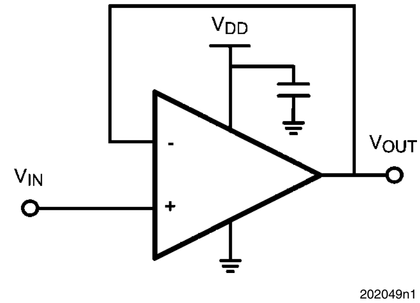
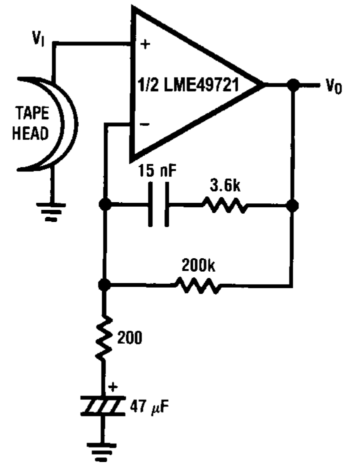


FIGURE 4. Buffer

Typical Applications

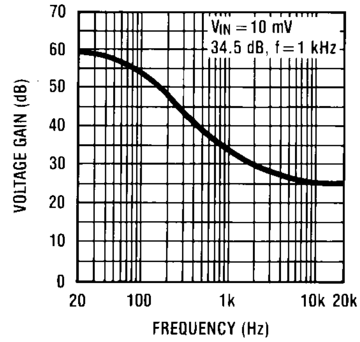
ANAB Preamp



202049n4

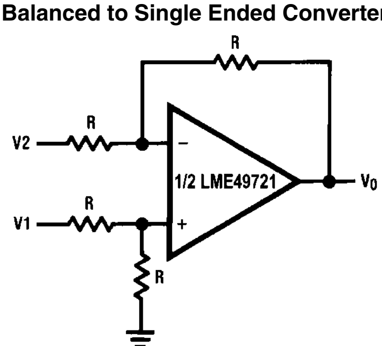
A_V = 34.5
F = 1 kHz
E_n = 0.38 μV
A Weighted

NAB Preamp Voltage Gain vs Frequency



202049n5

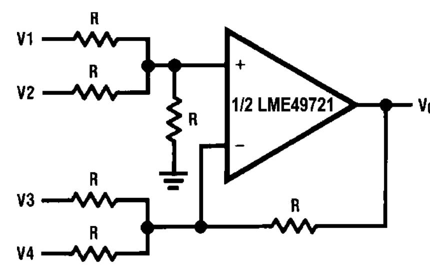
Balanced to Single Ended Converter



202049n6

V_O = V1–V2

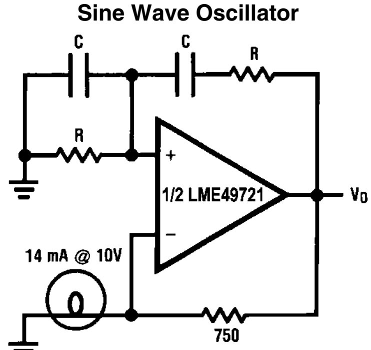
Adder/Subtracter



202049n7

V_O = V1 + V2 – V3 – V4

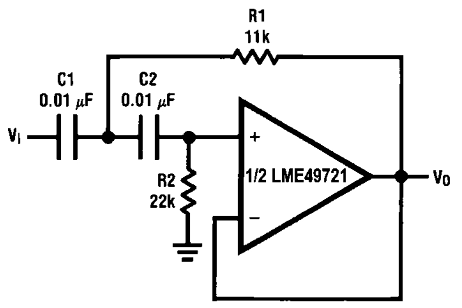
Sine Wave Oscillator



202049n8

$$f_O = \frac{1}{2\pi RC}$$

Second Order High Pass Filter (Butterworth)



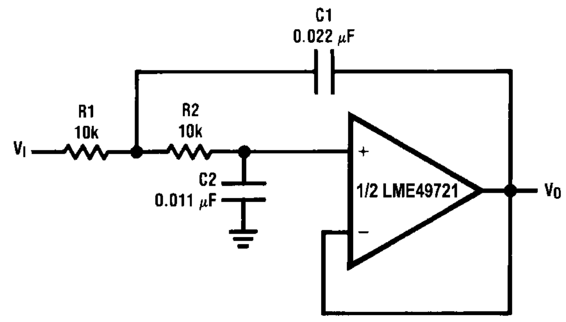
if C1 = C2 = C

$$R1 = \frac{\sqrt{2}}{2\omega_0 C}$$

$$R2 = 2 \bullet R1$$

Illustration is $f_0 = 1$ kHz

Second Order Low Pass Filter (Butterworth)



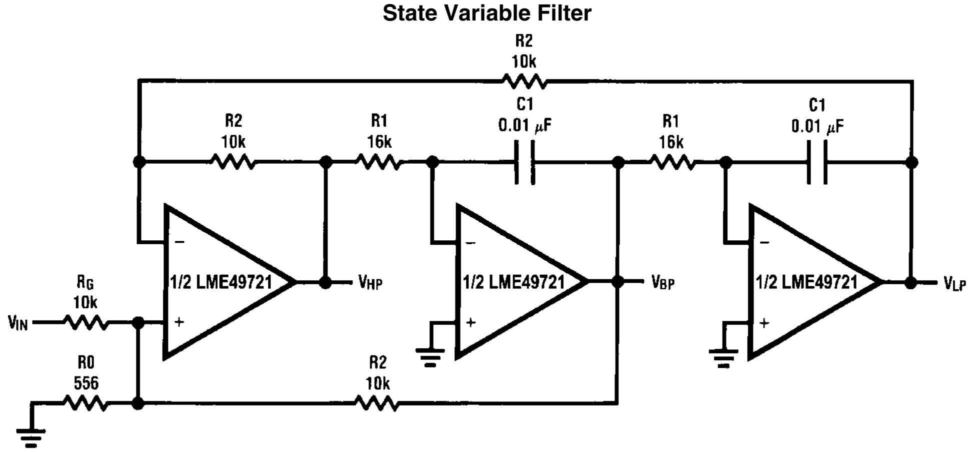
if R1 = R2 = R

$$C1 = \frac{\sqrt{2}}{\omega_0 R}$$

$$C2 = \frac{C1}{2}$$

Illustration is $f_0 = 1$ kHz

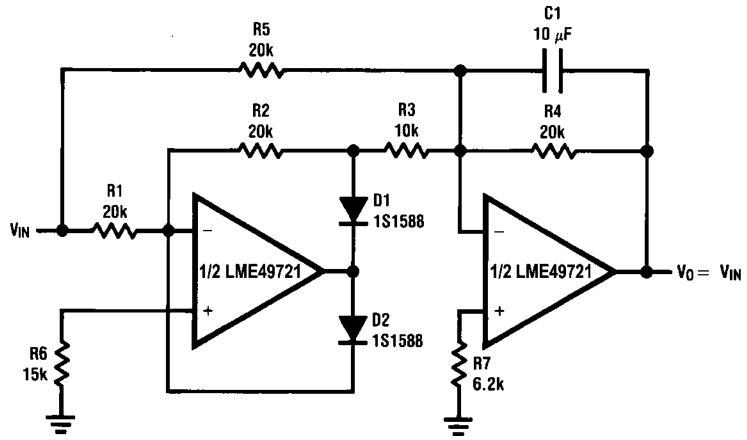
State Variable Filter



$$f_0 = \frac{1}{2\pi C1 R1}, Q = \frac{1}{2}\left(1 + \frac{R2}{R0} + \frac{R2}{RG}\right), A_{BP} = QA_{LP} = QA_{LH} = \frac{R2}{RG}$$

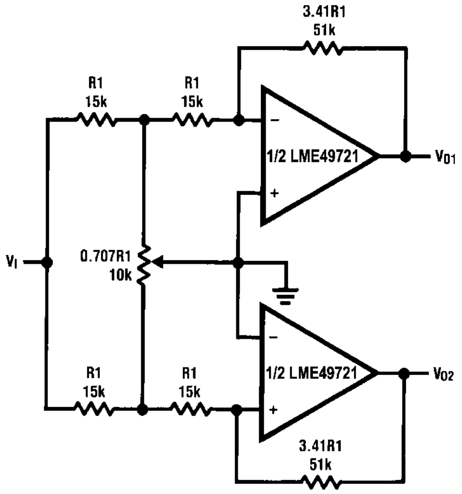
Illustration is $f_0 = 1$ kHz, $Q = 10$, $A_{BP} = 1$

AC/DC Converter



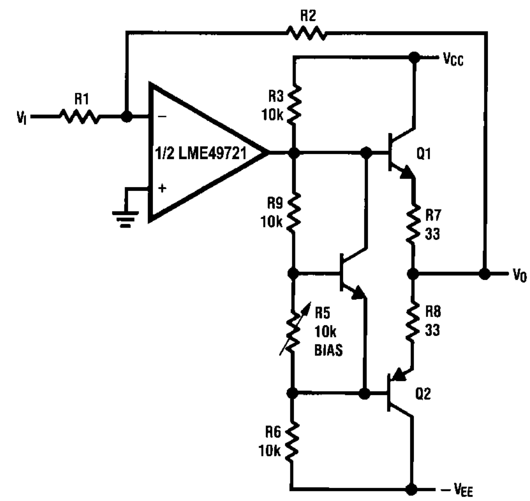
20204902

2 Channel Panning Circuit (Pan Pot)



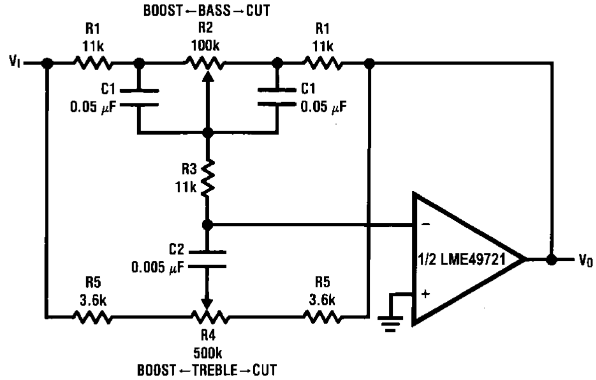
20204903

Line Driver



20204904

Tone Control



20204905

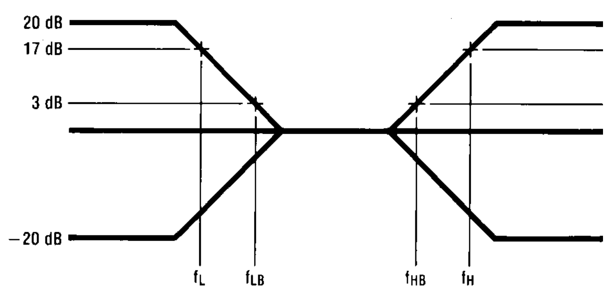
$$f_L = \frac{1}{2\pi R2C1}, f_{LB} = \frac{1}{2\pi R1C1}$$

$$f_H = \frac{1}{2\pi R5C2}, f_{HB} = \frac{1}{2\pi(R1 + R5 + 2R3)C2}$$

Illustration is:

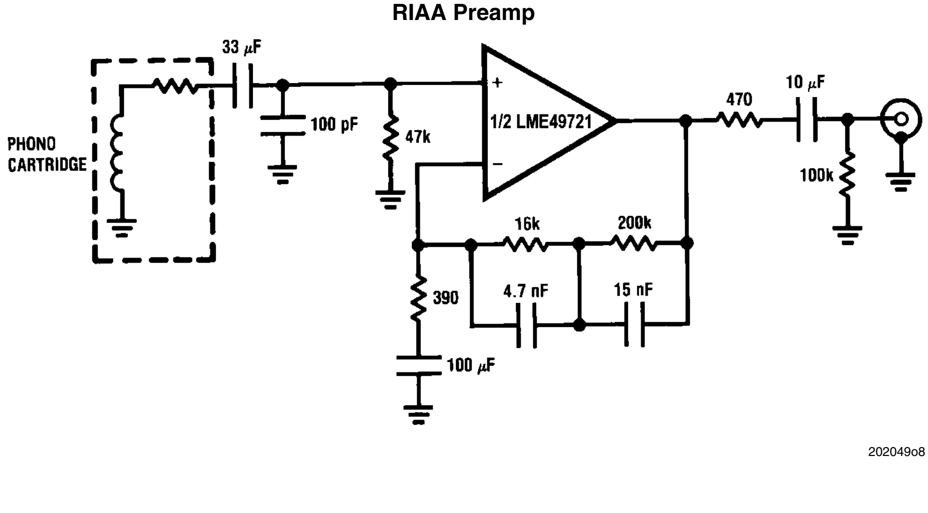
f_L = 32 Hz, f_{LB} = 320 Hz

f_H =11 kHz, f_{HB} = 1.1 kHz



20204906

RIAA Preamp



20204908

A_v = 35 dB

E_n = 0.33 µV

S/N = 90 dB

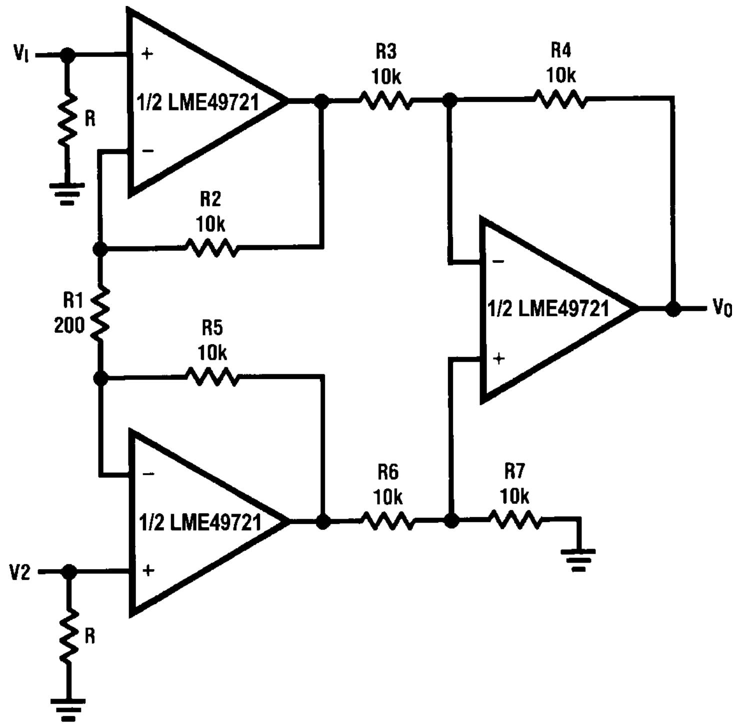
f = 1 kHz

A Weighted

A Weighted, V_{IN} = 10 mV

@f = 1 kHz

Balanced Input Mic Amp



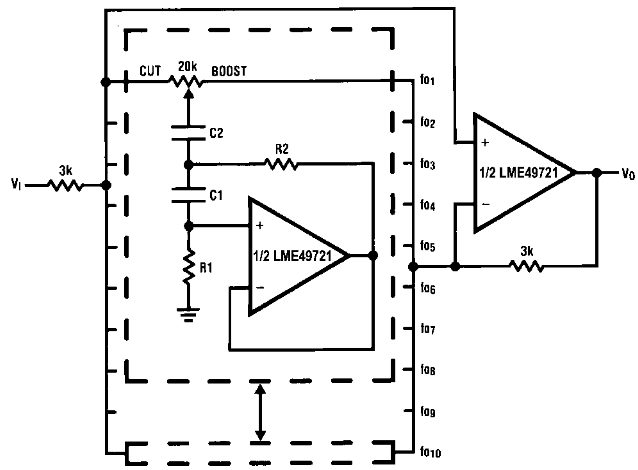
If R2 = R5, R3 = R6, R4 = R7

$$V0 = \left(1 + \frac{2R2}{R1}\right)\frac{R4}{R3}(V2 - V1)$$

Illustration is:

V0 = 101(V2 – V1)

10 Band Graphic Equalizer



fo (Hz)	C_1	C_2	R_1	R_2
32	0.12µF	4.7µF	75kΩ	500Ω
64	0.056µF	3.3µF	68kΩ	510Ω
125	0.033µF	1.5µF	62kΩ	510Ω
250	0.015µF	0.82µF	68kΩ	470Ω
500	8200pF	0.39µF	62kΩ	470Ω
1k	3900pF	0.22µF	68kΩ	470Ω
2k	2000pF	0.1µF	68kΩ	470Ω
4k	1100pF	0.056µF	62kΩ	470Ω
8k	510pF	0.022µF	68kΩ	510Ω
16k	330pF	0.012µF	51kΩ	510Ω

Note 8: At volume of change = ±12 dB

Q = 1.7

Reference: “AUDIO/RADIO HANDBOOK”, National Semiconductor, 1980, Page 2–61

Revision History

Rev	Date	Description
1.0	09/26/07	Initial release.
1.1	10/01/07	Input more info under the Buffer Amplifier.

Physical Dimensions inches (millimeters) unless otherwise noted

NS Package M08A

Notes

For the most current product information visit us at www.national.com

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